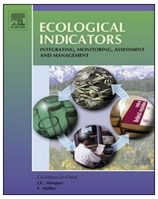
Ecological Indicators xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind



Original Articles

What drives the distribution of crab burrows in different habitats of intertidal salt marshes, Yellow River Delta, China

Shanze Li, Baoshan Cui*, Tian Xie, Junhong Bai, Qing Wang, Wei Shi

School of Environment, Beijing Normal University, State Key Joint Laboratory of Environmental Simulation and Pollution Control, Beijing 100875, China

ARTICLE INFO

Keywords:
Burrowing crab
Distribution pattern
Estuary
Mounds
Suaeda salsa
Wetland

ABSTRACT

Crabs play important roles in coastal ecosystems and are useful indicators for evaluating ecosystem health. Many previous studies have examined the distribution patterns of crabs among different habitats. However, we know little about what the key factors determining crab burrow distribution among types of habitats. Different kind of crab species may have different preferences of environmental conditions, here, we focus on the dominant crab species *Helice tientsinensis* in the Yellow River Delta. To identify the drivers of crab burrow distribution in intertidal marshes of the Yellow River Delta, we examined crab burrow density among seven habitats across different marsh zones, with reference to abiotic (water depth, soil hardness, water content, bulk density, porewater salinity, organic matter, total nitrogen and total carbon) and biotic (plant coverage, above- and belowground biomass, macrofauna species richness, abundance and biomass) factors that might explain crab burrow distribution patterns. Differences of all above factors were examined by one-way Analysis of Variance (ANOVA) among different habitats. The best single predictors of crab burrow density were tested by liner regression across the entire study area. Our results showed that patterns of crab burrow distribution were more strongly affected by abiotic drivers (water depth, water content, salinity, soil hardness, organic matter and total carbon) than biotic drivers. Crabs prefer habitats with softer and wetter edaphic conditions. In the future of coastal management, building habitats first, thereafter attracting crabs settling down and regulating feeding area of water birds and other benthic communities are good strategies to follow.

1. Introduction

Semi-terrestrial crabs play important roles in many coastal ecosystems including promoting nutrient cycling, processing matter deposition and providing food for birds and fishes (He, 2013; Hubner et al., 2015). Herbivorous crabs may strongly affect vegetation biomass and cause die-back zones in salt marshes (Coverdale et al., 2012). In other conditions, crab may facilitate plant growth by altering conditions of sediment (Smith et al., 2009; Aschenbroich et al., 2016). Crab burrowing increases the sediment-water interface (Koo et al., 2007), therefore increases the nutrients exchanges between sediment and water. In addition, crabs are important food resources for water birds and fishes in intertidal marshes (Iribarne et al., 2005; Chen et al., 2016b). Crabs can be used as indicators of intertidal marsh condition in coastal areas (Spivak et al., 1994; Mouton and Felder, 1996; Cardoni et al., 2007; Griffiths et al., 2007; Weilhoefer, 2011). For instance, fiddler crab burrows have been used as indicators for evaluating salt marsh recovery from Deepwater Horizon oil spill (McCall and Pennings, 2012). Ghost crabs have been used as indicators to illustrate global anthropogenic impacts including urbanizations and human trampling (Schlacher et al., 2016). Crab burrows, instead of crabs, have been widely used as indicators in many researches, since burrows counting is easy and rapid for estimating crab populations (da Rosa and Borzone, 2008; Weilhoefer, 2011; Schlacher et al., 2016; Stelling-Wood et al., 2016).

Many previous studies have examined the crab burrow distribution patterns among different habitats (Flores et al., 2005; da Rosa and Borzone, 2008; Hamasaki et al., 2011). Others have shown that water depth, plant communities (Mouton and Felder, 1996), soil water content (Reinsel and Rittschof, 1995), light, salinity (He and Cui, 2015), sediment characteristics (Spivak et al., 1994), food resources (He and Cui, 2015) and tides (Casariego et al., 2011b; Luppi et al., 2013) affect distribution of crabs. However, the distribution patterns of *Helice tientsinensis* crab in different saltmarsh zones of the Yellow River Delta remain unclear. Crabs in different ecosystems may have different preferences of environmental conditions (Vermeiren and Sheaves, 2014). *Helice tientsinensis* (Sesarminae) is the most common species of semi-terrestrial grapsidae crabs that inhabits intertidal marshes on the coasts

---

* Corresponding author at: School of Environment, Beijing Normal University, State Key Joint Laboratory of Environmental Simulation an Pollution Control, No. 19 Xinjiekouwai Street, Beijing 100875, China.

E-mail addresses: cuibs@bnu.edu.cn (B. Cui), xie.tian.1988@hotmail.com (T. Xie).

http://dx.doi.org/10.1016/j.ecolind.2017.11.003
Received 9 January 2017; Received in revised form 1 November 2017; Accepted 3 November 2017
1470-160X/ © 2017 Published by Elsevier Ltd.

of the Yellow River Delta, China (He, 2013; He and Cui, 2015). *H. tientsinensis* is omnivorous with many diet choices including fresh vegetable matter, leaf litter, organic debris, fungi, infanual communities and even eggs of water birds (He et al., 2015; Li et al., 2015). *H. tientsinensis* crab burrows mostly have a single entrance and are occupied by a single crab (Wang et al., 2015). Burrows of *H. tientsinensis* occur in many habitats across different marsh zones of intertidal salt marshes.

The objective of our study was to characterize the spatial distribution patterns of crab burrows among different habitats across marsh zones in the intertidal salt marshes of the Yellow River Delta. Another objective of this study was to identify the relationships between crab burrow distribution and environmental factors. In addition, the final objective of this study was to determine the main factors drive the distribution patterns of crab burrows in the Yellow River Delta, and to provide implications and suggestions in coastal wetland management.

2. Materials and methods

2.1. Study area

Our study area was located in an intertidal salt marsh (119°09′ E; 37°46′ N) of the Yellow River Delta (Fig. 1), with irregularly semi-diurnal tides and a warm-temperate climate (Li et al., 2016a). The Yellow River Delta is known as a key stopover for birds migration (Li et al., 2016b), breeding and wintering, and crabs are one of their important food resources. Most of the Yellow River Delta is occupied by the intertidal salt marshes. *Suaeda salsa* was present at higher densities, *Salicornia europaea* and *Tamarix chinensis* were present at lower densities in intertidal salt marshes (Li et al., 2016a). Across our studied region, the high marsh was mainly dominated by *S. salsa* community, with interspersed zones of *S. salsa* and *S. europaea*. The middle and low marshes were mainly dominated by large bare patches interspersed with *S. salsa* communities (Li et al., 2016a).

2.2. Sample collection and analysis

To examine the distribution pattern of crab burrows among different habitats across marsh zones, we selected 7 habitats across high, middle and low marshes in the fall of 2012. In the high marsh, we randomly set up 5 sampling sites (5 m × 5 m) in bare patches (High0), 5 sampling sites (5 m × 5 m) in *S. salsa* communities (High1) and 5 sampling sites (5 m × 5 m) in interspersed patches of *S. salsa* and *S. europaea* (High2). In the middle and low marshes, we randomly set up 5 sampling sites (5 m × 5 m) in bare patches (Middle0 and Low0) and 5 sampling sites (5 m × 5 m) in *S. salsa* communities (Middle1 and Low1), respectively. We collected three samples (1 m × 1 m) at each site. Thus, total of 105 sampling plots among 35 sampling sites in 7 habitats were sampled. In each sampling plot (1 m × 1 m), we counted the number of crab burrows with diameter over 10 mm. In this study, the high, middle and low marsh zones were identified by the regional tide levels data. Tide levels were estimated based on the astronomic tide model at the Dongyinggang tidal station (118°58′E, 38°06′N), cited from the National Marine Data and Information Service (NMDIS), China. Three habitats were located in the high marsh zone (H0:0.40 m, H1: 0.46 m, H2: 0.52 m), two habitats were located in the middle marsh zone (M0: 0.10 m, M2:0.22 m), and two habitats were located in the low marsh zone (L0: −0.07 m, L1: −0.05 m).

We collected data on abiotic and biotic factors that might affect distribution patterns of crab burrows. We measured water depth and soil conditions (soil hardness, water content, bulk density, porewater salinity, organic matter, total nitrogen and total carbon) in each sampling plot. Water depth was measured using a ruler. In each sampling plot, we collected soil cores (5 cm deep and 5.05 cm diameter) to examine all soil abiotic conditions. Soil hardness was recorded using a soil penetrometer. Soil cores were weighed and re-weighed before and after oven-dried at 60 °C for 48 h to determine soil water content and bulk density (He et al., 2012). Porewater salinity was measured from the resulting supernatant of a dry soil with deionised water (1:5 by volume) (Pennings et al., 2003). Soil organic matter was examined using the Walkley-Black Wet Combustion method (Bai et al., 2012). Soil total nitrogen (TN) and soil total carbon (TC) were determined using an Elemental Analyzer (Vario El, Germany).

We recorded all the plant species (*S. salsa* and *S. europaea*) at each sampling site and estimated their percent cover in three replicate quadrants (1 m × 1 m). In each sampling plot, we collected aboveground and belowground (20 cm deep) biomass in a 50 cm × 50 cm quadrat centered in each 1 m × 1 m plot. Plant biomass were dried for 3 days at 60 °C and weighed. In each sampling plot, we collected rectangular sediment samples (33 cm Length × 30 cm Width × 20 cm Depth) adjacent to each of the sampling plots using a stainless steel can-corer. We collected macrofauna that were retained on a 0.45 mm mesh sieve. We identified macrofauna under a dissecting microscope to the lowest possible level (usually to the species level). We counted the number of individuals of each taxa present in the core and measured the wet biomass comprised by each taxa.

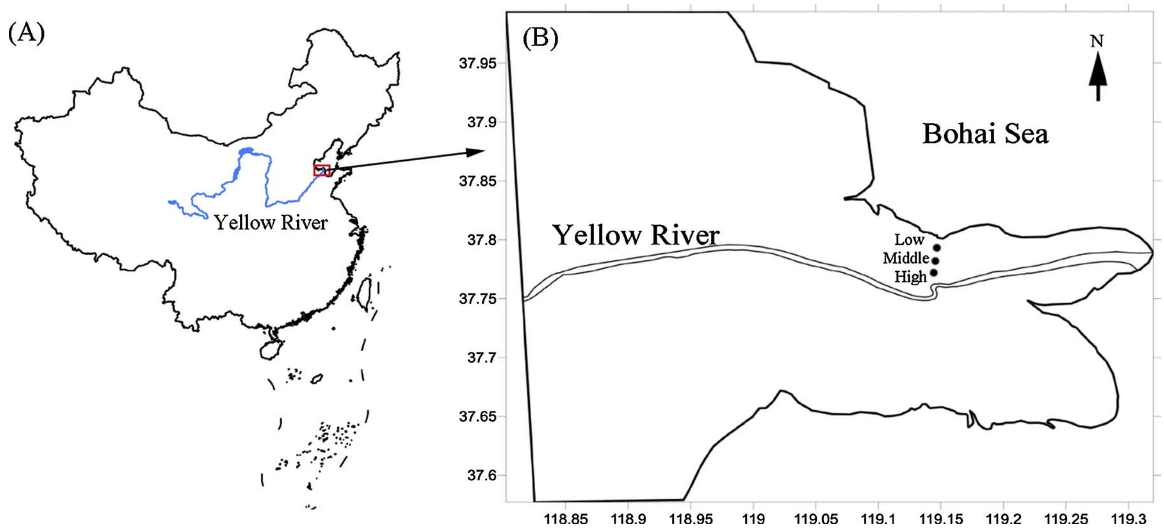


Fig. 1. Map of study area and sampling zones in the Yellow River Delta, China.